Habitat Improvement for Wildlife in North-Central Sonora, Mexico

Martha Martín-Rivera
Fernando Ibarra-Flores
Fred S. Guthery
William P. Kublesky, Jr.
Gustavo Camou-Luders
Jesus Fimbres-Preciado
Donald Johnson-Gordon

Abstract—Native vegetation of semiarid grasslands and desert ecosystems that comprise the Arbosufrutescent Desert scrub vegetation in north-central Sonora has been degraded by overgrazing, drought, farming, woodcutting, and a host of other activities over the past century. Several studies were conducted at "Rancho Grande" and at "Rancho El Carrizo," Sonora from 1992 to 1999 to evaluate the effect of several range improvement practices on wildlife habitat. Twenty-five-thousand seedlings of eight native shrubs and trees were transplanted on a site in north-central Sonora. Survival rates among species varied from 55 to 84 percent 1 year after transplanting and from 10 to 41 percent 3 years after planting. Re-establishment of native shrubs represents a promising technique that could restore native woody vegetation on degraded ecosystems that lack diversity. Habitat management by disking and shredding coupled with improvement in grazing management with short-duration grazing, have also resulted in improved native herbaceous conditions on thousands of acres of private ranches. These results are encouraging. The potential impact that re-establishment of native shrubs, control of undesirable brush species, and improvements in grazing management may have on wildlife occupying rangelands in north-central Sonora will be discussed.

Introduction

Extensive areas of desert rangelands that were once productive are now highly infested with less desirable brush species and toxic plants (Vallentine 1971). Overgrazing, droughts, frosts, accidental fires, land clearing for farming and grazing; and the extensive use of wood for fuel, fences, charcoal, and wood carving have caused drastic changes in the vegetation, resulting in low forage productivity, unprotected soils, and a high susceptibility for soil erosion (Scifres 1980; Ibarra and others 1996). Reduction of cattle numbers and good grazing management alone may not be sufficient to restore productivity on these deteriorated rangelands. In most cases range seeding with high quality grasses and shrubs may be the best alternative for restoring productivity (Vallentine 1971; Ibarra and others 1996). Browse species are important because they are a good source of food for humans, livestock, and wildlife; provide shelter, soil protection, and soil stabilization; improve soil fertility; and provide a favorable microhabitat for the establishment of other species (Whisenant and others 1982; Guthery 1986; Ibarra and Martin 1995).

Buffelgrass (*Cenchrus ciliaris* L.) is a warm season bunchgrass widely used in much of Mexico for revegetation following brush removal. Forage production of buffelgrass exceeds that of native grasses and stocking rates are frequently three to ten fold greater than on native rangelands (Martin and others 1995). Brittlebush (*Encelia farinosa* A. Gray) is a deciduous half shrub native to the Sonoran Desert (Benson and Darrow 1981), which infests buffelgrass stands. Densities of this species have almost doubled in 30 years on rangelands near Tucson, Arizona (Shreve and Hinckley 1937), and densities as high as 30,000 plants per hectare have been reported in buffelgrass seeded pastures in Sonora, Mexico (Ibarra and others 1986). High resin and oil contents make brittlebush a plant of low palatability for cattle and wildlife. As the species increase, density, cover, and forage production of buffelgrass declines (Ibarra and others 1996).

Masked bobwhite (*Colinus virginianus ridgwayi*) is an endangered specie restricted to the Buenos Aires National Refuge in Arizona, U.S.A., and to rancho El Carrizo and Rancho Grande in Sonora, Mexico. Densities of masked bobwhite have been drastically declining in the last 20 years, with an actual estimated bird population of close to 3,000 at these three locations. As a result, ranchers and range managers of both countries are applying grazing management and range improvement practices to restore bird population. Additionally, densities of Sonoran mule deer (*Odocoileus hemionus eremicus*) have been drastically declining in some ranches because of severe droughts, deficient range management practices, and poor wildlife management strategies.

In: McArthur, E. Durant; Fairbanks, Daniel J., comps. 2001. Shrubland ecosystem genetics and biodiversity: proceedings; 2000 June 13–15; Provo, UT. Proc. RMRS-P-21. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Martha Martín-Rivera and Fernando Ibarra-Flores are Range Scientists, INIFAP-CIRNO, Blvd. del Bosque # 7 Fracc. Valle Verde, Hermosillo, Sonora, Mexico, CP 83200. Fred S. Guthery is Wildlife Specialist, Department of Forestry, Oklahoma State University, 008 Agricultural Hall, Room C, Stillwater, OK 74078-6013. William P. Kublesky, Jr., is Wildlife Specialist, Buenos Aires National Wildlife Refuge, P.O. Box 109, Sasabe, AZ 85633. Gustavo Camou-Luders is a Producer, Rancho El Carrizo, Sierra Murrieta No. 168, Col. Loma Linda, Hermosillo, Sonora, CP 83150. Jesus Fimbres-Preciado is a Producer, Rancho Grande, Veracruz No. 33 Ote. Hermosillo, Sonora, CP 83200. Donald Jonson-Gordon is Professor of Range Management, UNISON-Departamento de Agricultura y Ganaderia. Km 21 Carretera a Bahia Kino, Hermosillo, Sonora, Mexico.

There is a lack of information on the establishment of browse species for cattle and wildlife in the Sonoran Desert. Also, there is not enough information about the effect of vegetation manipulation by mechanical control of unpalatable shrubs and grazing on range productivity and animal responses. A series of range improvement practices were conducted at "Rancho Grande" and "Rancho El Carrizo" from 1992 to 1999 with the following objectives: (1) to evaluate the seeding potential of several browse species by transplanting to restore range productivity, (2) to evaluate the effect of vegetation manipulation by mechanical means to increase forage production for cattle and wildlife, (3) to evaluate the effect of grazing systems on wildlife habitat recovery, and (4) to enhance species diversity and productivity for livestock and wildlife.

Material and Methods

The Rancho Grande site (29° 49' N Lat. and 111° 14' W Long.) is located 90 Km north of Hermosillo, Sonora, Mexico (fig. 1), at an elevation of 700 m on a gently sloping terrain (<5 percent). Mean annual precipitation is 320 mm, 75 percent of which occurs during the summer. Mean annual temperature is 24.5 °C, with a frost-free period of 345 days. Soils are deep sandy loams of granitic origin, with moderate permeability and a pH of 7.0.

The Rancho El Carrizo site (30° 0' N Lat. and 111° 12' W Long.) is located 120 Km north of Hermosillo, Sonora, Mexico (fig. 1), at an elevation of 750 m on a gently sloping terrain (<5 percent). Mean annual precipitation is 330 mm, 75 percent of which occurs during the summer. Mean annual temperature is 24.0 °C, with a frost-free period of 345 days. Soils are deep sandy loams and deep gravelly loams of granitic origin, with moderate permeability and a pH of 7.0.

Figure 1—Location of study sites, Sonora, Mexico.

Transplanting Browse Species

A study site was selected within the Arbosufrutescent Desert shrub vegetation type in the northwestern area of Sonora, Mexico. The site was located at Rancho Grande on a recently planted buffelgrass pasture. Twelve-thousand plants were transplanted in July 1996. Species planted were selected based on previous animal preference trails. Seed used for plant propagation was collected 1 year before at each study site. Plants were grown during 1 full year under nursery conditions before transplanting to achieve a height of 20 to 75 cm. Browse species were distributed randomly and planted every 5 m along contour furrows 40 cm in depth. Furrows were made at 20 to 50 m intervals with a back mounted "v" type plow pulled by a bulldozer.

Species were planted by hand on the bottom of the furrows using shovels. Species planted were: native mesquite [(*Prosopis juliflora*) (Swartz) DC.], chilean mesquite [*Prosopis chilensis* (Molina) Stuntz emend. Burkart], ironwood (*Olneya tesota* A. Gray), blue palo verde (*Cercidium floridum* Bentham), foothill palo verde [*Cercidium microphillum* (Torr.) Rose & Johnston], jojoba [*Simmondsia chinensis* (Link) Schneid], fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], and zamota (*Coursetia glandulosa* A. Gray). The site was fenced to protect it from cattle grazing. Plant survival (percent) and height (cm) were measured during the peak growing season of 1996 to 1999 by checking 100 previously marked plants by species.

Shredding for Brittlebush Control in Buffelgrass Pastures

This study was conducted at Rancho Grande on three adjoining buffelgrass pastures, 200 hectares each, in poor to regular condition. Pastures were shredded once during 1995, 1996, and 1997. Shredding at a height of 5 cm was conducted in April with a 5 m wide flail shredder powered by a tractor. Initial brittlebush density was 17,570 ± 3,125 plants per hectare, and canopy cover was 46 ± 8.4 percent across pastures. Initial buffelgrass density was 1.3 ± 0.4 plants per hectare, and basal cover was 5.2 ± 0.6 percent across pastures. Vegetational changes were monitored on three 10 x 20 m plots. Total grass and shrub density was estimated on three 10 m^2 permanent quadrats, and cover on three 20 m long transects per plot (Canfield 1941). Total forage production was estimated at the end of the summer growing season in each plot by clipping ten 1 m^2 quadrats per plot. Forage samples were oven dried at 65 °C for 72 hours and results were expressed in dry matter.

Improving Native Rangelands Infested With Brush by Disk Harrowing

Two thousand hectares of rangelands, dominated by the arbosufrutescent brush type, in poor to regular condition

and highly infested with catclaw mimosa [*Mimosa laxiflora* (Swarts.) DC.] and creosotebush [*Larrea tridentata* (Moc.&Sesse.) Cov.)], were improved by disk harrowing at rancho "El Carrizo" from 1992 to 1997. Disking at a depth of 20 cm was conducted from March to June by using a disk harrow with 36 disks mounted on the back of a D-4 bulldozer. Mainly catclaw mimosa and creosotebush were selectively controlled by disking, because about 40 percent of the total vegetation cover was composed of these species. Desirable brush and tree species protected during disking were blue palo verde, foot hill palo verde, mesquite, and ironwood. Main grass species present were three awn (*Aristida* spp.), 6 weeks needle grama [*Bouteloua aristidoides* (H.B.K.) Griseb], and rothrock grama (*Bouteloua rothrockii* Vasey). Total dry forage production was low and averaged 350 kg per hectare. Treated areas were protected during a full year from cattle grazing, and they were grazed light to moderate thereafter.

Forage production on disked pastures was estimated at the end of the summer growing season by clipping. Forage production increases by disking were compared with forage production in adjacent untreated pastures. Mortality of catclaw mimosa and creosotebush was estimated by comparing plant densities inside and outside the treated pastures. Masked bobwhite quail densities were estimated by direct observation and by call counts. Quail density increases in disked pastures were compared against bird densities estimated on adjacent untreated pastures. Densities of Sonoran mule deer on treated pastures was estimated by direct animal counting and population changes over time were compared with deer densities on untreated adjacent pastures.

Adopting Grazing Systems for Habitat Improvement

This study was conducted at rancho El Carrizo from 1992 to 1998. The two-thousand hectares of rangelands treated by disk harrowing to improve masked bobwhite quail habitat were subdivided into 12 small pastures. Pasture sizes varied from 140 to 200 hectares. A modified short-duration grazing system (SDG) was implemented in the ranch to control grazing. Stocking rates were set following biologists recommendations to remove no more than 60 percent of the total dry forage production available during the summer growing season of a given year. Grazing periods are set to be 7 days in each pasture during the summer growing season, and 15 days of grazing in each pasture during the rest of the year.

Forage production in the SDG was estimated at the end of the summer growing season by clipping. Forage production and stocking rate increases on the SDG were compared against forage production and stocking rates in adjacent pastures subjected to continuous grazing. Masked bobwhite quail densities were estimated by direct observation and by call counts. Quail density increases in the SDG pastures were compared to bird densities estimated on adjacent untreated pastures. Densities of Sonoran mule deer on pastures subjected to SDG were estimated by direct animal count and population changes over time were compared to deer densities in adjacent pastures subjected to continuous grazing.

Results and Discussion

Transplanting Browse Species

Total precipitation at "Rancho Grande" was 317, 353, 384, and 162.5 mm during 1996, 1997, 1998, and 1999 and was close to the long-term average of (320 mm). In general, growing conditions during all summers were adequate for species survival and growth. Precipitation distribution was adequate during all years, except for the summer of 1996, the year of planting, when more than 60 percent of the total rain occurred during the winter. Because of the dry conditions prevailing during the year of planting, approximately 10 liters of water were added to each plant during the summer of 1996.

Plant survival was different among species after the dry growing season of 1996, and varied from 55 to 84 percent. Between the winter of 1996 and the summer of 1999, 51 to 82 percent of the plants were killed by drought and insects and cattle grazing. Plant survival was different among species by the end of the summer growing seasons of 1997, 1998, and 1999. Species with the greatest survival rate after planting in the four summer growing seasons were native mesquite, chilean mesquite, foothill palo verde, blue palo verde, and ironwood with 41, 35, 33, 30, and 27 percent survival, respectively. Species with the lowest survival were zamota, fourwing saltbush, and jojoba, with 25, 15, and 10 percent survival, respectively.

Plant height was not different among species after the summer of 1996, but it differed in the summer growing seasons of 1997, 1998, and 1999. The height of transplanted species increased from 13 to 138 cm during the four summer growing seasons after planting. Species that achieved the greatest height were chilean mesquite and native mesquite with 138 and 137 cm, respectively. Jojoba had the lowest height with an average of 13 cm, and the height of the remaining species varied from 30 to 68 cm.

High densities of Sonoran mule deer, white tailed deer (*O. virginianus couesi*), javelina (*Tayassu tajacu*), and jackrabbit (*Lepus alleni*) were common at the study site. Low forage availability outside the exclusions during the dry period caused severe wildlife grazing on most planted species. Chilean mesquite (with no thorns), jojoba, and fourwing saltbush were the most preferred species by wildlife. Ten to 25 percent of the fourwing saltbush and jojoba plants were uprooted by wildlife within 3 weeks of planting.

Survival of transplanted shrubby forage species was adequate in the Sonoran Desert when planting was followed by a summer with below average precipitation. Mortality of the browse species was principally due to low moisture availability during the study period, grasshopper consumption, and wildlife grazing. Similar results have been reported with other browse species on rangelands (Whisenant and others 1982; Ueckert and others 1982), although greater plant survival can be expected in years with above average precipitation (Springfield 1970).

Results obtained show that browse consumption by wildlife may be an important factor affecting species survival after transplanting. Similar results had been reported with different browse species (Springfield 1970; Whisenant and others 1982). Watering transplanted species during drought

may be risky because plants with green foliage will attract more wildlife. Based on survival and growth characteristics, native mesquite, chilean mesquite, ironwood, blue palo verde, and foothill palo verde appear to have the greatest potential for range seeding in the Sonoran Desert. However, transplanting of these species may be feasible only where a few plants are needed (McMillan 1960). Although there is a high risk of seeding failures on areas with low rainfall, range seeding by transplanting browse species continues to be a future alternative for the restoration of deteriorated Sonoran Desert rangelands.

Good brush and grass cover along with an adequate food source is required to enhance masked bobwhite population recovery (Guthery 1986). Bobwhite habitat conditions are good to excellent on the pasture where browse species were planted. Although the pasture has been protected from cattle grazing during 2 years and has been grazed light to moderate for 2 consecutive years thereafter, no quail has been detected after call counts. Bobwhite possibly already inhabit the area, but it may be too soon to see big changes in bird densities after habitat improvement.

Densities of Sonoran mule deer have certainly increased on brush reseeded pastures. Mule deer numbers have almost doubled since 1996 after planting. Densities of deer were 1.0 per every 25 ± 4.5 hectares inside the shrub-seeded pasture and 1.0 per every 48 ± 5.9 hectares in the neighboring pastures. Browse species planted in this pasture have been found to be an important component of Sonoran mule deer diets (Ibarra and Martin 1995), consequently, this range practice will aid in deer habitat improvement and recovery.

Shredding for Brittlebush Control in Buffelgrass Pastures

Brittlebush was not significantly reduced by shredding and densities declined by 12.2 ± 3.5 percent among pastures. Brush canopy cover was always greater on the control plots as compared to shredded areas during the study period. Brush cover was 8.2 ± 1.9 percent after shredding, and 22.3 ± 3.5 percent in the three growing seasons after treatment application. Buffelgrass density averaged 1.9 ± 0.2 p/m^2 on untreated checks and 3.9 ± 0.3 p/m^2 on shredded areas in the three growing seasons after treatment .

Buffelgrass basal cover was consistently greater during all years on shredded plots. Grass cover averaged 5.2 ± 0.6 percent on untreated control plots and 13.0 ± 1.3 percent on shredded areas in the three growing seasons after shredding. Forage production of buffelgrass was greater on shredded plots during all years as compared to untreated controls. Forage production on shredded pastures varied from 1.9 to 2.7 ton/ha after the first growing season; from 3.5 to 4.1 ton/ha after the second summer growing season, and averaged 4.5 ton/ha after the third growing season. Cumulative forage production after three summer growing seasons on shredded stands was 7.82 ton/ha greater as compared to untreated plots.

Although mortality of brittlebush from shredding was low (8.7 to 15.7 percent) among pastures, top removal temporarily reduced brush canopy cover (Vallentine 1971). Brittlebush cover was reduced by 82 percent after shredding, but the species replaced 48 percent of its original cover three summer growing seasons after shredding. Similar results had been reported with these and other brush species in Mexico and Texas (Wright and Stinson 1970; Ibarra and others 1986). However, the rate of replacement of top growth is variable among species (Reynolds and others 1992), and depends directly on rainfall after shredding (Scifres 1980). Consequently, a faster rate of recovery on brittlebush may be expected when shredding is followed by years of above average precipitation.

In this study, recovery of buffelgrass stands after shredding may be attributed to temporary brush suppression and resulting plant competition reduction (Scifres 1980; Bovey and others 1986). The addition of plant debris to the soil surface after shredding may also protect the soil from erosion, reduce runoff, increase water availability, and add organic matter (Vallentine 1991); afterwards, oxidation of organic matter releases nutrients to the soil for plant use (Kononova 1968). The establishment of new grass seedlings was possibly enhanced by soil disturbance caused by branches, sticks, and shredding blades hitting the soil surface. Results suggest that shredding is an effective range improvement practice to restore productivity in buffelgrass pastures highly infested with brittlebush in the Sonoran Desert.

Although pastures have been rested from grazing during the year of shredding and they have been light to moderately grazed thereafter, it is uncertain if masked bobwhite densities have increased on treated pastures. No birds have been recorded after count calling, despite rancher cowboy reports that they have seen more birds in the area. Hopefully, habitat for quail has improved because brush cover of all other desirable brush and tree species were protected during shredding. Good brush cover is reported to improve habitat for bobwhite quail (Guthery 1986). Densities of mule deer have been consistently greater on shredded pastures as compared to untreated pastures. Deer counting during the fall of three consecutive years show 35 to 57 percent more deer, mainly does, in shredded pastures. The presence of more succulent forage of grasses and shrubs may account for deer population increases after shredding (Scifres 1980). This information suggests that habitat improvement of deteriorated buffelgrass pastures by shredding may play an important role in increasing mule deer populations.

Improving Native Rangelands Infested With Brush by Disk Harrowing

Precipitation at Rancho El Carrizo, Sonora, was close to the long-term average (325 mm) from 1994 to 1999, except for 1998 when only 203 mm of rainfall occurred. Total precipitation at the study site was adequate in quantity and distribution to promote significant vegetational changes after disking. Less than 30 percent of the catclaw mimosa and creosotebush plants were killed by disk harrowing. Plants that survived disking sprouted vigorously from the base and reached original sizes within 3 years of treatment application. Soil disturbance significantly increased density and cover of most grass and forbs species present in the site before disking. Bristlegrass (*Setaria* spp.), buffelgrass, sideoats grama [*Bouteloua curtipendula* (Michx) Torr.], and

tanglehead [*Heteropogon contortus* (L.) Beauv.] were species not present on the pasture before disking, but were also substantially increased after soil disturbance. These plants are reported as an important source of feed in masked bobwhite diets (Guthery 1986). Forage production on disked pastures varied from 750 to 1,100 kg per hectare and was two to threefold as compared to untreated pastures.

Sonoran mule deer populations were consistently greater during all years on disking improved pastures. Deer count estimations indicate that deer numbers were 40 to 65 percent greater in improved pastures as compared to adjacent untreated pastures. Greater forage availability and richer species diversity may be attracting more deer to feed inside the improved pastures. Density of mule deer has varied among years from 28 to 33 hectares per deer in disked pastures and from 45 to 51 hectares per deer on untreated adjacent pastures.

Call counts of masked bobwhite quail show that bird densities have at least doubled on disked pastures. Ranchers have reported seeing more birds on the area. Additionally, bobwhites have been recording even in areas where they were not found before. There is no doubt that habitat for masked bobwhite is improved after disking because cover of desirable brush and tree species were protected during treatment. Additionally, disking drastically increased some plants preferred by quail (Guthery 1986). The results of this study show that selective brush control by disking is an important habitat management tool for the recovery of masked bobwhite populations in the Sonoran Desert.

Adopting Grazing Systems for Habitat Improvement

The short-duration grazing system recently adopted in el Carrizo ranch in pastures previously rehabilitated by disking is significantly improving vegetation, cattle performance, and wildlife recovery. Combination of selective brush competition reduction, soil disturbance, forage production increase, and the control of animal grazing have resulted in greater ecological and economical benefits. Actual carrying capacity on treated pastures is at least two to threefold as compared to untreated pastures. Smaller pastures are facilitating the management of animals. The calf crop has been increased from 15 to 20 percent as compared to previous yearly records. Although animal gains are similar in continuous grazing, the number of animals in SDG almost doubled, despite the established forage utilization of 60 percent or less.

Densities of Sonoran mule deer have almost doubled within the SDG. Moderate to light grazing is possibly attracting more deer, as more nutritious feed remains available in the pastures. Masked bobwhite habitat conditions are good to excellent according to wildlife biologists throughout the SDG. Grazing is permitted in the system when cattle can graze forage without damaging masked bobwhite habitat. Controlling grazing intensity should improve herbaceous cover conditions and masked bobwhites will have more chances to colonize new areas within the pasture. Good grazing management is expected to yield improved habitat conditions for quail.

References

Benson, L., R.A. Darrow. 1981. Trees and shrubs of the southwestern deserts. University of Arizona Press. Tucson, AZ. 416 p.

Bovey, B.W., Meyer, R.E., Merkle M.G., and E.C. Bashaw. 1986. Effect of herbicides and hand weeding on establishment of kleingrass and buffelgrass. Journal of Range Management, 39:547–551.

Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry, 39:388–394.

Guthery, F.S. 1986. Beef brush and bobwhites. Quail management in cattle country. Golden Banner Press, Inc. 182 p.

Ibarra, F.A., Martin, M.H., Miranda H., and J.L. Luna. 1996. Seeding of forage brush species for the restoration of deteriorated rangelands in the Sonoran Desert. Abstracts 51st Annual Meeting. Society for Range Management. Guadalajara, Jalisco, Mexico. 63 p.

Ibarra, F.A., Martin, H.M., Torres L.R., Silva M.F., Morton H.L., and J.R. Cox. 1986. The brittlebush problem and potential control measures in buffelgrass pastures in Sonora, Mexico. Proceedings of the Western Society of Weed Science, 39:57–66.

Ibarra, F.F.A. and M.R. Martin. 1995. Establecimiento del Zacate Buffel. Guia Practica para el Establecimiento, Manejo y Utilizacion del Zacate Buffel (Eds. PATROCIPES A. C.), Patronato del Centro de Investigaciones Pecuarias del Estado de Sonora: 15–30.

Kononova, M.M. 1968. Transformations of organic matter and their relation to soil fertility. Soviet Soil Science, 2:1047–1055.

Martin-R.M., Cox, J.R., Alston, D.G., and F. Ibarra-F. 1995. Spittlebug (Homoptera: Cercopidae) life cycle on buffelgrass in Northwestern Mexico. Annals of the Entomological Society of America, 88:471–478.

McMillan, I.I. 1960. Propagation of quail brush (saltbush). California Fish and Game, 46, 507–509.

Reynolds, J.P., Fulbright, T.E., and S.L. Beasom. 1992. Mechanical rejuvenation to dampen seasonal variation in chemical composition of browse. Journal of Range Management, 45:589–592.

Scifres, C.J. 1980. Brush management—principles and practices for Texas and Southwest. Texas A&M University. 360 p.

Shreve, F., and A.L. Hinckley. 1937. Thirty years of change in desert vegetation. Ecology, 18:463-478.

Springfield, H.W. 1970. Germination and establishment of fourwing saltbush in the Southwest. Res. Pap. RM-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 46 p.

Ueckert, D.N., Petersen, J.L., McFarland, M.L., and R.L. Potter. 1982. Fourwing saltbush revegetation trials in west Texas. Brush Management and Range Improvement Research 1980-81. College Station, TX. CPR 3968–4014.

Vallentine, J.F. 1971. Range Development and Improvements. Brigham Young University Press. Provo, UT. 545 p.

Whisenant, S.G., Ueckert, J.L., and J.E. Huston. 1982. Forage shrub revegetation trial in West Central Texas. Brush Management and Range Improvement Research 1980–81. College Station, TX. CPR 3968–4014.

Wright, H.A., and K.J. Stinson. 1970. Response of mezquite to season of top removal. Journal of Range Management, 23:127–128.